Perception, 2013, volume 42, pages 302–320

doi:10.1068/p7371

The influence of symmetry on children's judgments of facial attractiveness

Larissa Vingilis-Jaremko, Daphne Maurer§
Department of Psychology, Neuroscience, & Behaviour, McMaster University,
1280 Main Street West, Hamilton, ON L8S 4K1, Canada; e-mail: maurer@mcmaster.ca
Received 11 September 2012, in revised form 3 March 2013

Abstract. In experiment 1, we examined developmental changes in the influence of symmetry on judgments of attractiveness by showing adults and children pairs of individual faces in which one face was transformed 75% toward perfect symmetry, while the other face was transformed by exaggerating its asymmetries by 75%. Adults and 9-year-olds, but not 5-year-olds, rated the more symmetric faces as more attractive than the less symmetric faces, although the effect was stronger in adults than 9-year-olds. The preference for symmetry was stronger for male than female faces, and stronger for adults' than children's faces. In experiment 2, comparisons of the symmetry of the original male and female faces revealed no measured differences but lower ratings by adults of symmetry in the male faces. Overall, the results suggest that the influence of symmetry on attractiveness judgments emerges after the age of 5 years, and matures after the age of 9 years. The stronger effects for adult viewers may reflect an increase in sensitivity to symmetry as experience with faces increases and/or as the visual system matures. As well, attractiveness may become more salient after puberty, so that honest signals of mate quality, such as symmetry, have a stronger effect for adult viewers, especially when judging adult faces.

Keywords: face perception, attractiveness, symmetry, development

1 Introduction

While it is often stated that "beauty is in the eye of the beholder", there is actually a high degree of agreement among individuals on what is attractive. Cross-cultural studies find high inter-rater agreement in attractiveness judgments (Bernstein et al 1982; Cunningham et al 1995; Johnson et al 1983; Langlois et al 2000; Perrett et al 1994) and, developmentally, infants look longer at faces rated by adults as attractive than those rated as unattractive (Langlois et al 1987; Samuels et al 1994; Slater et al 1998, 2000). Together, this evidence suggests that there is some universality in what people find to be attractive. These judgments influence interpersonal interactions through the "what is beautiful is good" stereotype, whereby more attractive individuals, including children, are judged as having more positive traits and treated more favourably than those judged as less attractive (Dion et al 1972; Langlois et al 2000).

One influence on adults' judgments of attractiveness is bilateral symmetry (see Wade 2010 for a review).[(1)] For example, when photographs of faces are manipulated to be perfectly symmetric by averaging each face with its mirror image, adults judge the perfectly symmetric versions to be more attractive than the original versions of the faces (Perrett et al 1999). Similarly, they

[(1)] Some studies published prior to 1999 did not find facial symmetry to be attractive (eg Kowner 1996; Langlois et al 1994; Samuels et al 1994). These studies used chimeric methods of manipulating symmetry in which the left side of the face was mirrored onto the right, and vice versa, creating two symmetric faces: one made of two left hemifaces, and the other of two right hemifaces. Chimeras, however, may not be appropriate for assessing the influence of symmetry on attractiveness judgments because they can create structural abnormalities in the face and can lead to odd-looking faces. A meta-analysis by Rhodes (2006) found that symmetry is attractive when faces are averaged with their mirror image to create symmetric stimuli, but not when chimeras are used. For that reason, we have not included studies using a chimeric method in our discussion of the adult literature.

§ Corresponding author.

rate faces manipulated to have increasing levels of symmetry to be increasingly attractive (Rhodes et al 1998). These studies, along with evidence that judged attractiveness covaries with natural variations in facial asymmetry, provide strong support for the conclusion that adults find bilateral symmetry attractive in faces (Grammar and Thornhill 1994; Mealey et al 1999; Perret et al 1999; Rhodes 2006; Rhodes et al 1998, 2001; Scheib et al 1999).

These studies manipulated two types of asymmetry that occur in faces: directional asymmetries, in which a trait is larger on one side of the midline in nearly all members of a species (eg in humans, the right side of the face is larger than the left side of the face; Simmons et al 2004), and fluctuating asymmetries that vary in direction and magnitude across members of a species and that have a normal distribution around the midline (Møller and Swaddle 1997). Because adults can adapt to the directional asymmetries that they see in virtually every face (Rhodes et al 2009), fluctuating asymmetries are likely to have more influence on judgments of attractiveness. Their influence might arise from the information they convey about phenotypic quality. Fluctuating asymmetries can arise from developmental instabilities, caused by a range of environmental (eg unusual climatic conditions, pollution, parasitism, high population density, low food quantity and quality) and genetic (eg genetic mutations, inbreeding, homozygosity) stressors (Møller and Swaddle 1997; Thornhill and Møller 1997). As such, fluctuating asymmetries may be an honest signal of phenotypic quality with lower levels signaling higher phenotypic quality (Møller 1990, 1997; Møller and Pomiankowski 1993; Møller and Swaddle 1997; Thornhill and Sauer 1992). Indeed, male and female high-school students living in slum districts of Ankara, Turkey have higher levels of facial asymmetry than those living in higher SES neighbourhoods (Özener 2010; Özener and Fink 2010). For the slum districts, the asymmetries were larger in male than in female faces. Additionally, men with higher levels of oxidative stress have higher levels of body asymmetry (women were not tested; Gangestad et al 2010). Consistent with this hypothesis, low levels of fluctuating asymmetries are related to mating success in several species, including humans (see Møller and Thornhill 1998 for a meta-analysis). For example, among humans, men and women with more symmetric bodies report more lifetime sexual partners than those with less symmetrical bodies (Thornhill and Gangestad 1994). Additionally, in a population of Mayans, where birth control does not influence fertility, more symmetric men had fewer serious illnesses, and more offspring, than less symmetrical men (women were not tested; Waynforth 1998). Symmetric mates, then, may have come to be preferred among many species, including humans, because they are associated with higher phenotypic quality. Symmetry may additionally be a stronger influence on the assessment of males than females (Møller and Thornhill 1998), as more males are available to reproduce than females in most human populations (Low 2001), creating stronger male–male than female–female competition. Thus, male traits could be expected to receive greater attention during assessment of potential mates and competitors (Trivers 1972).

In addition, symmetry may be attractive because it can be processed more fluently than asymmetry because of the redundancy of information. For adults, the detection of mirror symmetry emerges automatically and effortlessly in a wide variety of conditions, and symmetric stimuli are detected more quickly, are better discriminated, and are often remembered better than less symmetric stimuli (Garner and Sutliff 1974; Pomerantz 1977; Wagemans 1995). Moreover, the perception of vertical symmetry, as is present in human faces and bodies, appears to have a processing advantage over other orientations of symmetry, as adults detect vertically symmetric patterns more quickly and accurately than they detect symmetric patterns centred around other axis orientations (Wenderoth 1994). According to the processing-fluency hypothesis, stimuli that are processed more quickly and easily are preferred (Reber et al 2004). Studies of non-face objects and random-dot patterns provide support for this hypothesis (Halberstadt and Rhodes 2000; Winkielman et al 2006).

The processing advantage for vertical symmetry may then be the cognitive mechanism that leads us to prefer bilateral symmetry in faces and bodies. Evolution may have selected for these cognitive mechanisms; the salience of vertical symmetry in our environment and its value in our mate choice decisions may have favoured symmetry over asymmetry. Additionally, the presence of vertical symmetry in our environment may have favoured it over symmetry centred around other axis orientations.

By adolescence, bilateral symmetry influences attractiveness judgments of same-age faces. When younger adolescents (around the age of 11 or 12 years), and older adolescents (around the age of 13 or 14 years) are shown pairs of own-aged faces, in which one version of each face was made perfectly symmetric and the other version had the asymmetries increased by 50%, both groups selected the symmetric versions to be more attractive (Saxton et al 2009, 2011). The influence of symmetry on attractiveness judgments was stronger among older than younger adolescents when viewing male, but not female, faces, with no change in either group on a retest 10–13 months later (Saxton et al 2011). In another comparison of younger (12-year-olds) and older (13- to 14-year-olds) adolescents, children found symmetry to be attractive in faces of both their own and the other age, and older adolescents selected the more symmetric faces more frequently than younger adolescents (Saxton et al 2010). Both groups had a stronger preference for symmetry in the older than younger male faces. In sum, it appears that symmetry influences attractiveness judgments among adolescents, and that there is a change in the strength of its influence from early-adolescence to mid-adolescence. Because there was no adult comparison group, we do not know if the influence of symmetry is adult-like by mid-adolescence.

To our knowledge, there are no published data on when the influence of symmetry on judgments of attractiveness emerges during development. Infants do not show a looking preference for perfectly symmetric faces over original faces at 4 to 15 months (Samuels et al 1994)[(2)] or over faces in which the asymmetries were exaggerated by 50% at 5 to 8 months (Rhodes et al 2002). In fact, in the study of 5- to 8-month-old infants, first and longest looks were marginally longer toward the less symmetric faces, opposite of the direction predicted. Nevertheless, studies with patterns indicate that infants can perceive vertical symmetry. 4-month-old infants can discriminate vertically symmetric from asymmetric and horizontally symmetric patterns, and process vertically symmetric patterns more efficiently than asymmetric or obliquely symmetric patterns, as measured by time to habituation (Bornstein and Krinsky 1985; Bornstein et al 1981; Fisher et al 1981). At 12 months of age, but not at 4 months of age, infants look longer at vertically symmetric patterns than asymmetric patterns, while there is no looking preference for horizontally symmetric patterns at either age (Bornstein et al 1981). Infants thus are sensitive to vertical symmetry, which may have a special status early in perceptual development (Bornstein and Krisky 1985). It is unclear, however, whether this is also the case for symmetry in faces.

The purpose of our study was to explore the influence of bilateral symmetry on children's judgments of facial attractiveness in the period between infancy and adolescence. As there is no evidence of an influence of symmetry on attractiveness judgments prior to early adolescence, we tested 5-year-olds, an age when children can complete enough trials to generate reliable individual data, and 9-year-olds, a prepubescent age when most aspects of basic visual sensitivity are adult-like (Adams and Courage 2002; Ellemberg et al 1999; Lewis et al 2004). We presented children and adults with two versions of individual faces, in which one version was transformed 75% toward perfect symmetry, while the other version was transformed by exaggerating its asymmetries by 75%. Participants chose which face in each

[(2)] This study paired original and chimeric faces, a pairing that does not lead to consistent preferences in adults (see footnote 1), as was also true in this study.

pair they found more attractive, a method that is easier for young children than rating scales. We used both child and adult faces as stimuli because children may have more experience with the faces of same-age peers than of adults, and because both children and adults have an own-age bias in processing faces (Anastasi and Rhodes 2005; Hills and Lewis 2011; however, see Macchi Cassia 2011 for evidence of a processing advantage for adult faces even in children). We used faces of adults, 4- to 5-year old children (matching the recent experience of the 5-year-olds), and 8- to 9-year old faces (matching the recent experience of the 9-year-olds). Because Saxton and colleagues (2009, 2010, 2011) found changes during adolescence for male but not female faces, we included blocks with faces of both genders at all three ages. This also allowed us to examine whether the influence of symmetry is greater for male than female faces, as predicted by some evolutionary accounts.

2 Experiment 1

2.1 *Participants*

Participants were twenty-four adults (aged 18 to 25 years), twenty-four 9-year-olds (±3 months), and twenty-four 5.5-year-olds (±3 months). All participants were white, and half at each age were male. Child participants were recruited from a database of names of mothers who had volunteered shortly after the birth of their child to be contacted about future studies. Adults were undergraduate university students. Child participants received a toy, and adults received payment or course credit for participation. Participants were visually screened and had normal or corrected-to-normal vision; adults and 9-year-olds had normal stereoacuity as tested by the Titmus test of stereoacuity, and had a Snellen acuity of 20/20 or better, measured on a Lighthouse eye chart. Criteria were relaxed for 5-year-olds to 3/3 animals and 5/9 circles correct on the Titmus test of stereoacuity, equivalent to 100 s of arc of disparity instead of the adult norm of 40 s of arc, and a Snellen acuity of 20/30 or better measured with the Cambridge Crowding Cards, as vision is still maturing at this age (Adams and Courage 2002; Ellemberg et al 1999). An additional three 9-year-olds and two 5-year-olds were run but excluded because they were inattentive ($n = 1$), were out of the age range ($n = 1$), or did not pass our visual screening criteria ($n = 3$).

2.2 *Stimuli*

Stimuli were full-face, colour digital photographs of the faces of white adult women, adult men, 8- to 9-year-old girls, 8- to 9-year-old boys, 4- to 5-year-old girls, and 4- to 5-year-old boys. Faces were photographed with the subject facing the camera, with a neutral expression, and evenly lit. Adult models, and parents of children gave permission for their photographs to be manipulated and used in research. Adobe Photoshop CS was used to remove major blemishes and other irregularities from the faces, such as food. Faces that had the reflection of two catch lights in the eyes (because two catch lights were present when the models were photographed) had the right catch light removed from each eye with the Photoshop brush tool, to make the faces look more natural. Each face was manually delineated with 189 landmark points outlining features and the face shape. Each face was then averaged with its mirror-image to create a perfectly symmetric version. The original face was then warped 75% toward its perfectly symmetric version, or had its asymmetries exaggerated by 75%[3] changing the shape of the faces, but maintaining original texture (see Tiddeman et al 2001). This was done for 16 faces from each group to create 96 pairs of faces in total. Because we did not want participants' judgments to be influenced by distortions in the hairstyle, external features and hair were removed by placing a grey background around the outline of each face.

[3] As in previous studies, this procedure manipulates all types of asymmetries concurrently, both those that are directional and those that are fluctuating.

Although this change made the faces less naturalistic, it also prevented decisions based on flukes of hairstyle and encouraged judgments based on the physiognomy of the faces. Faces within each group were standardised for size based on interpupilary distance. Images were scaled to be approximately life-size for each age; from a viewing distance of 70 cm, adult faces subtended a visual angle of approximately 15 deg in height and 11 deg in width; 9-year-old faces subtended a visual angle of approximately 14 deg in height and 10.5 deg in width; and 5-year-old faces subtended a visual angle of approximately 13 deg in height and 10.5 deg in width (see figure 1). Images were 751 horizontal by 993 vertical pixel resolution (adults), 738 horizontal by 978 vertical pixel resolution (9-year-olds), 681 horizontal by 965 vertical pixel resolution (5-year-olds). The faces were presented on a HP 20555 SH249, 22 inch LCD Monitor with screen resolution set to 1024 pixels × 768 pixels. Although the original faces came from different sets of faces taken under different photographic conditions, participants made choices between a pair of faces that originated from the same original face. Thus, the two versions of each face always had the same resolution and lighting.

Figure 1. [In colour online, see http://dx.doi.org/10.1068/p7371] Low-symmetry (left) and high-symmetry (right) versions of an 8-year-old girl's face.

2.3 *Design*

We used a blocked within-subject design, with faces blocked by age and gender (16 for each group of faces) and the order of stimulus pairs within each block randomised for a total of 96 trials per participant. The side on which the more symmetric face appeared was randomised within each block for each participant. Blocks were counterbalanced with a Latin-square design. Adults and 9-year-olds were tested in one session, and 5-year-olds were tested in two separate sessions with identical counterbalancing, except divided across the two sessions.

2.4 *Procedure*

This study received ethics clearance from the institutional Research Ethics Board, and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). After explaining the procedure, we obtained written consent from adult participants and parents of child participants, and verbal consent from the children. We then gave participants the following instructions in a game-like format:

"An evil monster snuck into the lab and made copies of all my friends! Now I need your help to figure out who is my real friend and who is a copy. The monster didn't do a perfect job, so the only way to tell the difference between my real friends and the copies is that the real person looks nicer, prettier, or more attractive. Can you help me pick out the real person? Every time you see two faces on the screen, help find my real friends by choosing the face that is better looking, more handsome, or cuter."

We used a number of words throughout the experiment to describe the concept of attractiveness including *prettier*, *more handsome*, *nicer looking*, *better looking*, *cuter*, and *more attractive.* We used multiple words to be sure that the children understood the choice we were asking them to make. Children as young as 3 years give reliable attractiveness judgments in the same direction as those of adults for girls', boys', and adults' faces when instructed using the words *pretty and cute*, or the word *handsome* (Cooper et al 2006; Dion 1973; Langlois and Stephan 1977). Additionally, pre-schoolers are able to give detailed descriptions of the concept of attractiveness, a result suggesting that young children have an understanding of the concept (Dion 1973). After asking participants if they understood the procedure, they were given 10 criterion trials in which they were presented with pairs of objects the monster had copied. On each trial, one of the two objects was more faded, broken, or tattered than the other. On each trial, participants selected the "real" object, which was the object that looked better, or nicer. All participants successfully completed criterion trials with 100% accuracy and moved onto the main experiment. Trials were self-paced, and responses were made by clicking on the image with a mouse, which initiated the next trial. 5-year-old participants took a break after each block, and completed the first 3 blocks on the first testing day, and the second 3 blocks on the second testing day. Visual screening occurred after the first block in conjunction with the first break. 9-year-old participants completed 3 blocks, were then visually screened, then returned to the experiment to complete the remaining 3 blocks. Adult participants were visually screened, then completed all 6 blocks. All participants were allowed to take additional breaks as needed. Participants were debriefed with information about the purpose of the study and with information about the "Beauty is Good" stereotype following completion of the experiment.

2.5 *Results*

For each participant, we calculated the mean proportion of trials on which the more symmetric face was selected for each group of faces.[4] There were no outliers in any age group defined as being greater than 3 standard deviations from the mean.

To assess whether participants of each age selected the more symmetric faces more frequently than expected by chance, we performed a one-tailed one-sample *t*-test comparing the means of each face set to chance (0.5) for each age group, controlling for multiple comparisons with Bonferroni correction at $\alpha = 0.008$. Adult and 9-year-old participants selected the more symmetric face more frequently than chance for all face sets (all ps < 0.001; see figure 2). 5-year-old participants, by contrast, did not select the more symmetric face more frequently than chance (all ps > 0.033). Without Bonferroni correction, 5-year-olds selected the more symmetric adult male ($t_{23} = 1.935$, $p = 0.033$) and 9-year-old girl faces ($t_{23} = 2.567$, $p = 0.009$), significantly more often than expected by chance (all other ps > 0.066).

To compare the strength of the effects of symmetry across age and face sets, we preformed a repeated-measures ANOVA with the within-subject factors of face age (5 years, 9 years, adult) and face sex, and between-subject factors of participant age (5 years, 9 years, adult), and participant sex. The ANOVA revealed main effects of participant age ($F_{2,66} = 32.82$, $p < 0.001$, $\eta_p^2 = 0.499$), face age ($F_{2,132} = 4.29$, $p = 0.016$, $\eta_p^2 = 0.061$), face sex ($F_{1,66} = 8.76$, $p = 0.004$,

[4] The means for the 5-year-old female face set were calculated based on 15 rather than 16 face pairs because of a coding error.

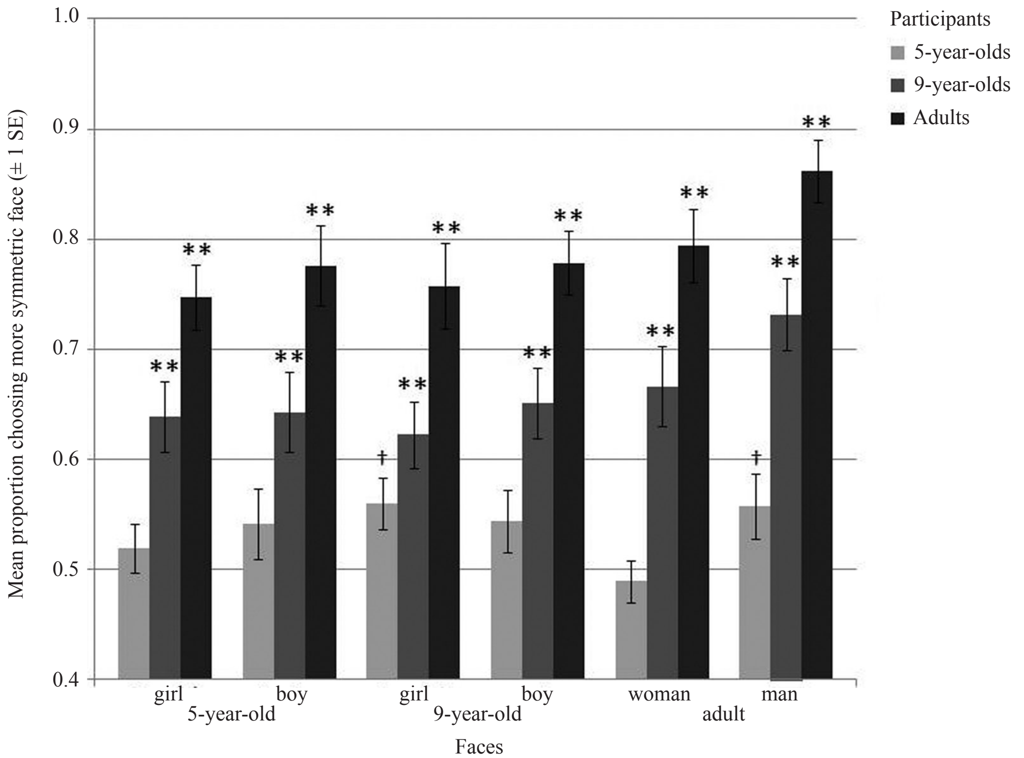

Figure 2. Mean proportion of trials on which the more symmetric face was selected by 5-year-old, 9-year-old, and adult participants for each face category. Note: †$p < 0.05$, *$p < 0.008$, **$p < 0.001$.

$\eta_p^2 = 0.117$), and an interaction between participant age and face age ($F_{4,66} = 2.49$, $p = 0.046$, $\eta_p^2 = 0.070$). The effect of face sex reflected a stronger effect of symmetry on choices for male than female faces (see figure 2). To analyse the interaction, we split the data by participant age, and performed separate repeated-measures ANOVAs for 5-year-old, 9-year-old, and adult participants with the within-subject factor of face age (5 years, 9 years, adult). The analysis revealed no significant effects among 5-year-old participants, and a main effect of face age among 9-year-old participants ($F_{2,46} = 4.20$, $p = 0.021$, $\eta_p^2 = 0.154$), and among adult participants ($F_{2,46} = 6.73$, $p = 0.003$, $\eta_p^2 = 0.226$). We followed up the effect of face age for 9-year-old and adult participants with paired samples *t*-tests comparing means for the faces of 5-year-olds, 9-year-olds, and adults, adjusting for multiple comparisons with Bonferroni correction at $\alpha = 0.017$. In 9-year-old participants, there were no differences in the selection of more symmetric faces between 5-year-old and 9-year-old faces ($t_{23} = 0.17$, $p = 0.866$), or between 5-year-old and adult faces ($t_{23} = -2.35$, $p = 0.028$). However, 9-year-olds selected more symmetric faces more frequently in adult ($M = 0.70$, SD = 0.16), than 9-year-old faces ($M = 0.64$, SD = 0.13; $t_{23} = -2.86$, $p = 0.009$). In adult participants, there were no differences between 5-year-old and 9-year-old faces ($t_{23} = -0.31$, $p = 0.763$); however, adults selected the more symmetric faces more frequently in adult ($M = 0.83$, SD = 0.13) than 5-year-old faces ($M = 0.76$, SD = 0.15; $t_{23} = -3.16$, $p = 0.004$), and in adult than 9-year-old faces ($M = 0.77$, SD = 0.14; $t_{23} = -3.54$, $p = 0.002$).

We performed a complementary item analysis across faces rather than across participants by calculating the proportion of participants of each age (5 years, 9 years, and adult) selecting the more symmetric face for each group of faces (16 face pairs × 6 groups of faces). For every age of participant, this produced 16 preference scores for each of the 6 groups of faces.[5]

[5] The calculations in the 5-year-old female face set were based on the same 15 faces used for the analysis in experiment 1.

The null hypothesis states that the mean of the preference scores should be 50%, with half the raters selecting the more symmetric face. To assess whether more participants than expected by chance selected the more symmetric faces, for each age of participant we calculated 6 one-tailed one-sample *t*-tests comparing the mean preference score for each age and sex of face to chance (0.5), controlling for multiple comparisons with Bonferroni correction at $\alpha = 0.008$. None of the mean preference scores across face pairs was significantly different from chance for 5-year-old participants with Bonferroni correction. Without Bonferroni correction, mean preference scores were greater than chance for 9-year-old girl faces ($M = 0.56$, SD = 0.109; $t_{15} = 1.98$, $p = 0.022$), 9-year-old boy faces ($M = 0.544$, SD = 0.089; $t_{15} = 1.98$, $p = 0.033$), and men's faces ($M = 0.556$, SD = 0.101; $t_{15} = 2.27$, $p = 0.019$) (all other *p*s > 0.091). The mean preference scores across stimuli for each of the 6 groups of faces were significantly above chance for 9-year-old and adult participants (all *p*s < 0.001). When we took the mean preference score across all faces for each age of participant and calculated a one-sample *t*-test comparing the mean preference score to chance, we found that 5-year-olds' ($M = 0.534$, SD = 0.100; $t_{94} = 3.47$, $p < 0.001$), 9-year-olds' ($M = 0.659$, SD = 0.111; $t_{94} = 13.99$, $p < 0.001$), and adults' ($M = 0.786$, SD = 0.108; $t_{94} = 25.91$, $p < 0.001$) preference scores were above chance.

We additionally performed a repeated-measures ANOVA on the item scores with the within-subject factors of face age (5 years, 9 years, adult) and face sex, and between-subject factors of participant age (5 years, 9 years, adult) and participant sex. We found main effects of participant age ($F_{2,90} = 145.77$, $p < 0.001$, $\eta_p^2 = 0.764$), of face age ($F_{2,180} = 5.97$, $p = 0.003$, $\eta_p^2 = 0.062$), and face sex, with more raters choosing the more symmetric faces among male than female faces ($F_{1,90} = 11.73$, $p = 0.001$, $\eta_p^2 = 0.115$). A-posteriori comparisons using the Tukey HSD test indicated that more 9-year-olds ($M = 0.659$, SD = 0.111) selected more symmetric faces than 5-year-olds ($M = 0.536$, SD = 0.010) ($p < 0.001$), and more adults ($M = 0.786$, SD = 0.108) selected more symmetric faces than 9-year-olds ($p < 0.001$) or 5-year-olds ($p < 0.001$). We followed up with paired-samples *t*-tests comparing means for 5-year-old, 9-year-old, and adult faces, controlling for multiple comparisons with Bonferroni correction at $\alpha = 0.017$. We found that more participants selected the more symmetric faces in adult ($M = 0.684$, SD = 0.160) than 5-year-old faces ($M = 0.625$, SD = 0.163; $t_{95} = -3.52$, $p < 0.001$). Without Bonferroni correction, marginally more participants selected the more symmetric faces in adult than 9-year-old faces ($M = 0.652$, SD = 0.134; $t_{95} = -1.91$, $p = 0.060$).

2.6 *Discussion*

Our results indicate that both 9-year-olds and adults found symmetry to be attractive in faces. There was little evidence of an influence of symmetry on 5-year-olds' attractiveness judgments and its influence increased between the age of 9 years and adulthood. We additionally found that symmetry was a stronger influence on attractiveness judgments in adult than child faces, and in male than female faces.

This is the first study, to our knowledge, that has explored the influence of symmetry on attractiveness judgments between infancy and adolescence. Our results indicate that symmetry begins to influence facial attractiveness judgments reliably after the age of 5 years, and its influence reaches adult levels after the age of 9 years, a pattern suggesting a long developmental trajectory. It is possible that 5-year-olds could not even see the differences between the pairs of faces, a possibility that will be taken up in the general discussion. As the differences between face pairs in this study were exaggerated to likely be larger on average than the symmetry differences between faces in the real world, our results suggest that bilateral symmetry is unlikely to influence the attractiveness judgments of 5-year-olds in the real world.

The greater influence of symmetry on attractiveness judgments in male than female faces is consistent with findings that adolescents selected the symmetric face over the more asymmetric companion face more frequently for male than female faces when shown mid-adolescent (but not young adolescent) faces (Saxton et al 2009, 2010, 2011). From the standpoint of cognitive fluency, the greater influence of symmetry on attractiveness judgments in male faces is difficult to explain, because infants already show evidence of easier processing of female than male faces (see Ramsey et al 2005; Ramsey-Rennels and Langlois 2006), likely because of greater experience with female faces (Rennels and Simmons 2008). The stronger influence of symmetry on attractiveness judgments in male faces is less surprising from the standpoint of evolutionary explanations based on sexual selection (see introduction). Relatedly, it is possible that fluctuating asymmetry is larger, and hence more salient in male faces. However, the evidence is at best mixed. Manning (1995) found no differences in mean levels of FA between the bodies of males and females in a sample of 70 adults, or 100 children aged 5–12 years. However, in another group of 60 adults, Manning et al (1997) found higher levels of FA in the bodies of males than females. In a study of mandibular symmetry, Melnik (1992) found greater asymmetry in boys than girls at younger ages, but no sex difference by the age of 14 years. By contrast, a large study of school children in rural Jamaica found lower levels of asymmetry in boys than girls, which was mainly driven by asymmetries in elbow width (Trivers et al 1999). In sum, while our finding that symmetry had a greater influence on attractiveness judgments in male faces than female faces is not unique, it is unclear whether there may be peculiarities in our specific face sets, whether male faces vary more or less than female faces in fluctuating asymmetry in the general population, or whether fluctuating asymmetries are expressed more in males than females only in stressful environmental conditions, as seen in the slum districts of Ankara, Turkey (Özener 2010; Özener and Fink 2010).

The stronger influence of symmetry on attractiveness judgments in adult than child faces is unexpected, as Livshitz and Kobylianski (1989) found decreasing levels of fluctuating asymmetry from infancy to adulthood, and Melnik (1992) found decreasing levels of mandibular asymmetry from young childhood to early adulthood. A large-scale study examining fluctuating asymmetries of British children aged 2–18 years found that asymmetries decreased from 2 to 10 years, increased in adolescents at 11–15 years, and decreased again after the age of 15 years, a decrease that was maintained to the age of 18 years (Wilson and Manning 1996). Children's faces may then be more asymmetric than adult faces, possibly caused by differential rates of growth on the two sides of the body (Melnik 1992). Our finding of a greater influence of symmetry on adult than child faces could arise if we are more forgiving of asymmetries in children's faces because they tend to be more prevalent and/or it may reflect a processing advantage for adult faces because of the early and continuous exposure to adults' faces throughout development (see Macchi Cassia 2011).

In experiment 2, we compared the amount of asymmetry in our 6 face sets to see if differences based on sex or age of face could account for the stronger influence of symmetry on judgments of male faces and of faces of adults. Specifically, we examined whether our face sets match the differences reported in the literature (less asymmetry in adult faces). These data will help to distinguish whether our results could be caused by an unusual pattern of asymmetries in our face sets (greater asymmetries in our adult than child faces that are not typical of the population), or whether our stimuli are typical and symmetry may be a stronger influence on attractiveness judgments in older than younger faces and in male than female faces, as fluctuating asymmetries may be more informative for adult male faces.

3 Experiment 2

To test whether the effects of age and sex of face on attractiveness judgments in experiment 1 could be caused by mean differences in symmetry across our specific face sets, we measured the amount of asymmetry in the original unwarped faces in each set, and had adults rate the symmetry of those faces. Rhodes et al (1998) found that adults accurately rated symmetry differences among adult faces that had been manipulated to create low, medium, high, and perfectly symmetric versions of each face. Because in Scheib et al (1999), women did not accurately rate the symmetry of men's faces (despite finding symmetry to be attractive in men's faces), we also compared these ratings to actual measurements of symmetry in the original faces.

3.1 *Participants*

Participants were twenty-four white adults (aged 18 to 35 years; half male). All were students at McMaster University and met the same visual screening criteria as described in experiment 1. Participants volunteered, or participated in exchange for course credit.

3.2 *Stimuli*

Stimuli were the original, unwarped images that were used to create the symmetry stimuli in experiment 1. As in experiment 1, the images had been created by using Adobe Photoshop CS to remove major blemishes and the second catch light from each eye. External features and hair were removed by placing a grey background around the outline of each face. Faces subtended the same visual angle as in experiment 1.

3.3 *Procedure*

After obtaining consent, participants viewed the faces individually and were asked to rate how symmetric each face looked on a 5-point scale. Each face appeared individually in the centre of the computer screen, and the anchors (1) *very asymmetric*, and (5) *very symmetric* appeared in the top left and right corners of the screen. The instructions "How symmetric is this face?" were centred at the top of the screen. Faces appeared in random order within blocks counterbalanced by age and sex of face with a Latin-square design. There were 16 faces within each of the 6 face categories, for a total of 96 trials. Participants were told the age and sex of the group of faces they would be viewing prior to rating each block. Faces appeared on the screen until participants made a response with the keyboard, which then initiated the next trial.

3.4 *Results*

For each participant, we calculated the mean symmetry rating for each group of faces (see footnote 5). A repeated-measures ANOVA with the within-subject factors of face age (5 years, 9 years, adult) and face sex, and the between-subject factor of participant sex revealed main effects of face age ($F_{2,44} = 5.99$, $p = 0.004$, $\eta_p^2 = 0.214$), face sex ($F_{1,22} = 16.06$, $p = 0.001$, $\eta_p^2 = 0.422$), qualified by an interaction between face sex and face age ($F_{2,44} = 5.79$, $p = 0.006$, $\eta_p^2 = 0.208$). Non-significant effects included the main effect participant sex ($F_{1,22} = 3.69$, $p = 0.068$, $\eta_p^2 = 0.144$), and interactions between face age and participant sex ($F_{2,22} = 1.81$, $p = 0.835$, $\eta_p^2 = 0.008$), and between face age, face sex, and participant sex ($F_{2,22} = 1.42$, $p = 0.252$, $\eta_p^2 = 0.061$). To break down the face sex by face age interaction, we did separate paired-samples *t*-tests comparing male and female faces for each age of face, correcting for multiple comparisons with Bonferroni correction at $\alpha = 0.017$. The analysis revealed that participants rated adult male faces to be less symmetric than adult female faces ($t_{23} = 4.98$, $p < 0.001$), but there were no differences between male and female 9-year-old faces ($t_{23} = 2.28$, $p = 0.032$) or 5-year-old faces ($t_{23} = 0.989$, $p = 0.333$).

Paired-samples t-tests comparing the different ages of faces for each sex of face, correcting for multiple comparisons with Bonferroni correction at $\alpha = 0.017$, revealed no significant differences among female faces of different ages (all ps > 0.13). In male faces, participants perceived adult faces to be less symmetric than 5-year-old faces ($t_{23} = 4.29$, $p < 0.001$) and 9-year-old faces ($t_{23} = 4.21$, $p < 0.001$). In a-posteriori analysis, paired-samples t-tests adjusting for multiple comparisons with Bonferroni correction at $\alpha = 0.008$, revealed that adult male faces were rated to be less symmetric than all other groups of faces (all ps < 0.005; see figure 3).

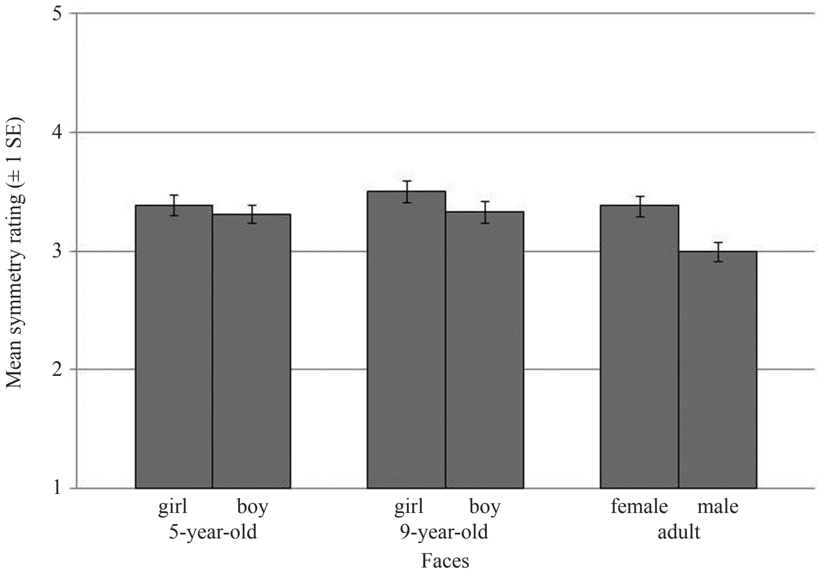

Figure 3. Mean symmetry ratings on a 5-point scale by adults of the original, untransformed faces (1 = *very asymmetric*, 5 = *very symmetric*).

3.5 *Symmetry measurements*

The procedure was similar to that described by Scheib et al (1999) and Penton Voak et al (2001). We used 6 pairs of corresponding bilateral points on each face to calculate measures of horizontal and vertical asymmetry. Calculations were based on bilaterally paired points at the outer corner of the eyes, the inner corner of the eyes, the outer edge of the cheekbones, the outer edge of the nostrils, the outer corner of the lips, and the outer edge of the jaw. Horizontal asymmetry refers to the difference for two corresponding points in the distance from the vertical midline. As points farther from the vertical midline exert a greater influence on an overall horizontal asymmetry measurement for the face than points closer to the midline, we took z-scores for each pair of points across all face sets. We then took the sum of the absolute value of the z-scores for the 6 pairs of horizontal asymmetry measurements to gain an overall measure of horizontal asymmetry for each face. Vertical asymmetry refers to the deviation of corresponding points from a level horizontal plane. The measurement for each face was based on the sum of the vertical differences, converted to z-scores for consistency. We additionally calculated a measurement of total asymmetry for each face by adding the absolute values of the z-scored vertical asymmetry and horizontal asymmetry measurements for each face. We performed separate repeated-measures ANOVAs for vertical asymmetry, horizontal asymmetry, and total asymmetry with the factors of face sex (male, female), and face age (5 years, 9 years, adult; see footnote 5), and found no main effect of face sex ($F_{1,14} = 0.718$, $p = 0.411$) or of face age ($F_{2,28} = 0.758$, $p = 0.478$), and no interaction between face sex and face age ($F_{2,28} = 0.402$, $p = 0.673$; figure 4).

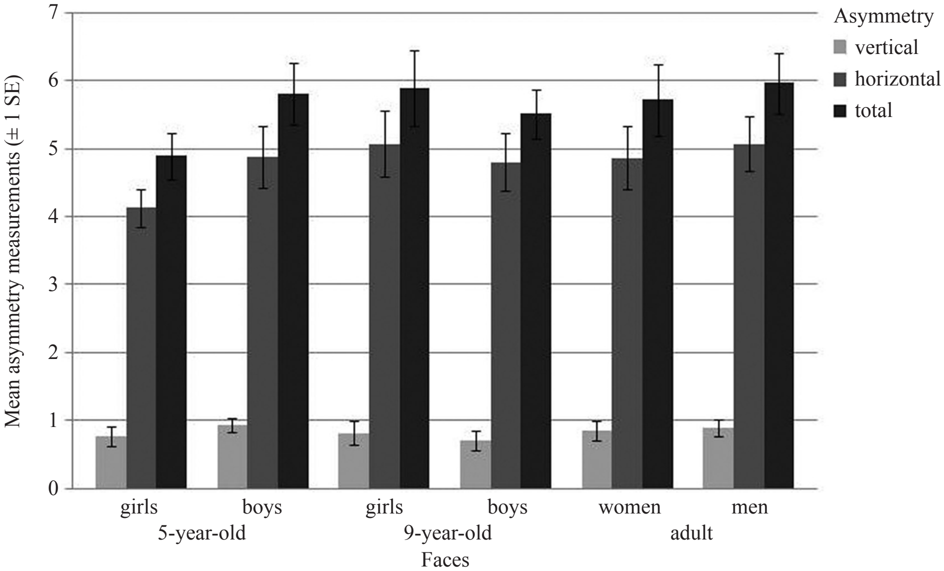

Figure 4. Mean asymmetry measurements for each group of faces. Higher numbers refer to higher levels of asymmetry.

3.6 *Discussion*

One result of experiment 1 was that symmetry exerted a stronger influence on adults' and 9-year-olds' attractiveness judgments for adult than child faces. In experiment 2, age of face did not affect adults' ratings of symmetry or our measurements. Combined, the data indicate that symmetry has more influence on judgments of attractiveness for adult than child faces, even though the face sets of different ages did not differ in average symmetry. In the general discussion, we consider the possible explanations for this effect.

Another result of experiment 1 was a stronger influence of symmetry on judgments of attractiveness for male than for female faces, regardless of age. In experiment 2, adults rated adult male faces to be less symmetric than all other groups of faces. There were no differences, however, in mean levels of asymmetry among the groups of faces according to our symmetry measurements. Thus, symmetry exerted a greater influence on the attractiveness judgments of children and adults when viewing male faces of adults or children, but our measurements indicated no sex differences in asymmetry, and adults' ratings did not differ except for rating adult male faces to be less symmetric. The discrepancy could reflect inaccurate measurement or ratings, and/or adults could have greater sensitivity to small variations in symmetry in male than in female faces.

It is possible that our symmetry measurements are inaccurate, as 2-D measurements of 3-D stimuli are inaccurate if the face is rotated even to a small degree away from a front-face view, making one side of the face appear to be larger than the other (Penton-Voak et al 2001). Adult raters, who take viewpoint into account when processing faces, might have been less affected by such hypothetical rotations. It is unlikely, however, that adult male models would have been more likely to rotate their heads than would other groups. Alternately, it is possible that adults were inaccurate when rating the symmetry of the faces. Although they can accurately rate symmetry differences in faces that have been manipulated to have low, medium, high, or perfect symmetry (Rhodes et al 1998), they may not be able to explicitly pick out subtle variations in symmetry in original faces of the type we used here, despite being affected by exaggerations of those asymmetries when making judgments of attractiveness. Our results are similar to those of Scheib et al (1999) who had women rate the symmetry of men's faces, and found only weak correlations between the symmetry ratings and actual measurements of symmetry.

Finally, it is possible that humans are more sensitive to asymmetries in adult male faces than in other groups of faces. Among most human populations, more males are available to reproduce than females (Low 2001). This creates stronger male–male competition over females compared to female–female competition over males and, as a consequence, male traits are expected to receive greater attention during assessment of potential mates and competitors (Trivers 1972). Indeed, the ratio of males to females to be judged alters the strength of the preference for symmetry, so that, when there is a higher proportion of males than females, symmetry has a stronger influence on female's judgments of attractiveness. (Watkins et al 2012). Our research suggests that these effects may carry over between the sexes, such that both sexes respond more strongly to the symmetry of men's than women's faces, and do so even in children's faces.

4 General discussion

We found that symmetry has clear influence on attractiveness judgments in 9-year-olds and adults, but only a weak, if any, influence on the judgments of 5-year-olds. This is the first evidence, to our knowledge, of the influence of symmetry on attractiveness judgments in pre-adolescent children. It is unlikely that the largely random performance of 5-year-olds was caused by children's poor understanding of the task, weak attention, or poor motivation, as all participants completed the criterion trials successfully, and averageness influenced the attractiveness judgments of children of the same age when they were tested with a similar procedure (Vingilis-Jaremko and Maurer, in press).

Combined with previous evidence, our results suggest a very long developmental trajectory for the influence of symmetry on judgments of attractiveness: a preference appears to be just emerging about the age of 5 years (this study), to strengthen by the age of 9 years (this study), and to increase further during adolescence (Saxton et al 2009, 2010, 2011). This pattern contrasts with the influences of feature height and of averageness on children's judgments of attractiveness that are already evident at or by 5 years of age (Cooper et al 2006; Vingilis-Jaremko and Maurer, in press). Nevertheless, those influences, like symmetry, are weaker throughout middle childhood than they are in adults (Cooper et al 2006; Vingilis-Jaremko and Maurer, in press).

There are several reasons the developmental trajectory for the influence of symmetry might be so long. First, the differences in symmetry between the two members of each pair were subtle and hence may have been difficult for children to detect. There is evidence that infants can distinguish asymmetric from vertically symmetric patterns as early as at 4 months of age [Bornstein et al 1981; see Bornstein and Stiles-Davis (1984) for evidence of discrimination in children aged 4 to 6 years] and that by the age of 1 year they have a looking preference for vertically symmetric patterns. However, it may take longer for them to become adept at detecting small differences in the degree of symmetry in a vertically symmetric pattern, such as the subtle differences present in faces. Indeed, children's sensitivity to the global structure present in dot patterns, moving dots, or biological motion continues to improve until the age of 9–12 years (Hadad et al 2011; Lewis et al 2004). So does their sensitivity to small differences in the location of internal facial features (Baudouin et al 2010; Mondloch et al 2002). Other immaturities of the visual system could have made it difficult for 5-year-olds to perceive the differences between faces. Contrast sensitivity does not become adult-like until the ages of 7 to 9 years, and grating acuity is not adult-like until the age of 6 years (Adams and Courage 2002; Ellemberg et al 1999). The 5-year-old age group may then have had greater difficulties perceiving the differences between the faces, which could limit or remove the influence of symmetry on their attractiveness judgments. Nevertheless, there was evidence that 5-year-olds could at least detect the asymmetries in some of the faces, as there was an influence of symmetry on their judgments of attractiveness when we collapsed the data across all faces to maximise power. As our stimuli vary more in symmetry than faces in a typical population, our findings suggest that, in everyday social interactions, symmetry has no, or at best minimal, influence on 5-year-olds' perceptions of attractiveness.

A second and related possibility is that poorer visual sensitivity in children prevents any processing advantage for symmetry. It has been hypothesised that adults may prefer symmetrical patterns because the redundancy of information leads to faster and more efficient processing, associated with a general tendency to find stimuli that are processed more easily to be attractive (Reber et al 2004). One can quantify differences between groups (or conditions) in processing efficiency by using a procedure that distinguishes differences in internal noise from differences in efficiency. In this procedure, the limits on processing of external stimuli are estimated by superimposing external noise (random variations in pixel luminance) on the stimuli and then estimating internal noise and efficiency from the shape of a function relating performance to level of external noise in log-log coordinates (Lu and Dosher 1999). Internal noise limits performance only at high levels of external noise and can result from stochastic fluctuations of neural responses, receptor sampling errors, and information loss during neural transmission (Lu and Dosher 1999). Inefficiency in processing the signal limits performance at all levels of external noise. Either higher levels of internal noise or less efficiency could limit children's preferences based on processing fluency, particularly for stimuli with very subtle differences, such as the faces differing in symmetry used in this study. Jeon et al (2012) recently used this approach with children aged 5, 7, and 9 years and adults in a paradigm in which subjects had to detect low-contrast gratings embedded in noise. Sensitivity improved between the ages 5 and 9 years, and again from the age of 9 years to adulthood. Computer modelling suggested that the improvements resulted from decreases in internal noise and increased efficiency. These visual limitations at the ages of 5 and 9 years are likely to reduce processing fluency, and thereby limit processing-based preferences when differences between stimuli are subtle.

A third possible explanation for the long developmental trajectory is that symmetry begins to strongly influence judgments of facial attractiveness only when children become old enough to think about mating, at which point its influence should be stronger for adult than children's faces. As reviewed in the introduction, symmetry may be an honest signal of phenotypic quality, and hence it is adaptive for symmetry to influence mate choice (see discussion of experiment 1). If this hypothesis is correct, there might be a sharp increase in the influence of symmetry after puberty, with a milder or no influence before then. Indeed there is an increase in the influence of symmetry on attractiveness judgments within adolescence, although the rate of increase at puberty is unknown, as prepubescent children were not tested in these studies (Saxton et al 2009, 2010, 2011).

A final possible explanation is that the gradual accumulation of experience in differentiating among faces from childhood to adulthood increases sensitivity to differences in symmetry when making judgments of attractiveness. There is evidence that the development of many aspects of face processing, including attractiveness judgments, is influenced by experience with faces (eg Cooper et al 2006; De Heering et al 2010; Hills and Lewis 2011; Macchi Cassia et al 2009; Mondloch et al 2006). For example, 3-year-old children with high levels of interaction with peers, like adults, judged faces with low feature height, as is present in children's faces, as more attractive than faces with high feature height. By contrast, 3-year-olds with low levels of peer interaction exhibited no preference between faces with low, average, and high feature height. Experience with peer faces may then have tuned children's attractiveness judgments toward the proportions of those faces (Cooper et al 2006). Additional evidence for a role of experience comes from the findings that the influence of symmetry on adults' judgments of attractiveness is greater for upright than inverted faces, and that their ability to detect small variations in symmetry is better for unaltered than contrast-reversed faces, and possibly better for upright than inverted faces (Little and Jones 2006; Rhodes et al 2005). Even brief periods of biased experience can change attractiveness judgments in both children and adults. Adapting 8-year-olds and adults to faces with either compressed or expanded features leads them to increase their attractiveness ratings of faces in the distorted direction, compared to before adaptation (Anzures et al 2009). These brief periods of biased experience probably affect attractiveness judgments by biasing a norm, or prototype face. When the biased input ends, exposure to the normal range of human faces will reset the norm to near the population average. Experiential refinement of the norm and the dimensions of the face space in which it is centred (Rhodes and Leopold 2011) may contribute to developmental improvements in detecting subtle differences among faces, including symmetry. Through this process, children may adapt to directional asymmetries that are common across human faces (eg the right side of the prototype face may become larger than the left: Rhodes et al 2009), and become more sensitive to fluctuating asymmetries. However, the finding of a strong influence of symmetry on judgments of attractiveness in Hadza adults, a hunter-gather group in Tanzania, that was equivalent for the Hadza faces of the type they had experienced and the European faces they had rarely seen (Little et al 2007) suggests that the preference may not arise from experience and/or that by adulthood it generalises to all types of adult faces.

These four explanations are not mutually exclusive. Increased visual sensitivity could allow children to extract more information from faces, and thereby allow them to form more useful dimensions in a multi-dimensional face space and a more veridical norm, both of which would promote processing fluency. This improved sensitivity could have more impact on judgments of attractiveness after puberty. All of these proximal mechanisms could, in turn, underlie the evolutionary advantage afforded by the influence of symmetry on mate choice.

Future studies could evaluate these explanations by assessing changes in the influence of symmetry at the transition to puberty by testing prepubertal, pubertal, and postpubertal children with adult same and opposite-sex faces. It would also be useful to compare these groups to young and older adults. If postpubertal interest in mating is critical, the effects should be stronger in postpubertal adolescents and young adults than in the other groups. Another future direction would be to assess developmental changes in symmetry discrimination among faces and patterns, an approach that would elucidate the role of changes in visual sensitivity in the increasing influence of symmetry on judgments of facial attractiveness during childhood.

Acknowledgments. We thank Renata Samigullina, Dana Shen, and Megan Hophing for help with the collection of data, and David Feinberg for contributing a subset of the face photographs that we used to create stimuli, for advice on creating stimuli, and for comments on an earlier draft of the manuscript. We thank Cathy Mondloch for contributing a subset of the face photographs that we used to create stimuli. This research was supported by a grant from the Canadian Natural Sciences and Engineering Council (9797) to Daphne Maurer. Larissa Vingillis-Jaremko was supported by an NSERC CGS D.

References

Adams R A, Courage M L, 2002 "Using a single test to measure human contrast sensitivity from early childhood to maturity" *Vision Research* **42** 1205–1210

Anastasi J S, Rhodes M G, 2005 "An own-age bias in face recognition for children and older adults" *Psychonomic Bulletin & Review* **12** 1043–1047

Anzures G, Mondloch C J, Lackner C, 2009 "Face adaptation and attractiveness aftereffects in 8-year-olds and adults" *Child Development* **80** 178–191

Baudouin J, Gallay M, Durand K, Robichon F, 2010 "The development of perceptual sensitivity to second-order facial relations in children" *Journal of Experimental Child Psychology* **107** 195–206

Bernstein I H, Lin T, McClellan P, 1982 "Cross- vs. within-racial judgments of attractiveness" *Perception & Psychophysics* **32** 495–503

Bornstein M H, Ferdinandsen K, Gross C G, 1981 "Perception of symmetry in infancy" *Developmental Psychology* **17** 82–86

Bornstein M H, Krinsky S J, 1985 "Perception of symmetry in infancy: The salience of vertical symmetry and the perception of pattern wholes" *Journal of Experimental Child Psychology* **39** 1–19

Bornstein M H, Stiles-Davis J, 1984 "Discrimination and memory for symmetry in young children" *Developmental Psychology* **20** 637–649

Cooper P A, Geldart S S, Mondloch C J, Maurer D, 2006 "Developmental changes in perceptions of attractiveness: a role of experience?" *Developmental Science* **9** 530–543

Cunningham M R, Roberts A R, Barbee A P, Druen P B, 1995 "Their ideas of beauty are, on the whole, the same as ours: Consistency and variability in the cross-cultural perception of female physical attractiveness" *Journal of Personality and Social Psychology* **68** 261–279

De Heering A, De Liedekerke C, Deboni M, Rossion B, 2010 "The role of experience during childhood in shaping the other-race effect" *Developmental Science* **13** 181–187

Dion K K, 1973 "Young children's stereotyping of facial attractiveness" *Developmental Psychology* **9** 183–188

Dion K, Berscheid E, Walster E, 1972 "What is beautiful is good" *Journal of Personality and Social Psychology* **24** 285–290

Ellemberg D, Lewis T L, Liu C H, Maurer D, 1999 "Development of spatial and temporal vision during childhood" *Vision Research* **39** 2325–2333

Fisher C B, Ferdinandsen K, Bornstein M H, 1981 "The role of symmetry in infant form discrimination" *Child Development* **52** 457–462

Gangestad S W, Merriman L A, Thompson M E, 2010 "Men's oxidative stress, fluctuating asymmetry and physical attractiveness" *Animal Behaviour* **80** 1005–1013

Garner W R, Sutliff D, 1974 "The effect of goodness on encoding time in visual pattern discrimination" *Perception & Psychophysics* **16** 426–430

Grammar K, Thornhill R, 1994 "Human (*Homo sapiens*) facial attractiveness and sexual selection: The role of symmetry and averageness" *Journal of Comparative Psychology* **108** 233–242

Hadad B, Maurer D, Lewis T L, 2011 "Long trajectory for the development of sensitivity to global and biological motion" *Developmental Science* **14** 1330–1339

Halberstadt J, Rhodes G, 2000 "The attractiveness of nonface averages: implications for an evolutionary explanation of the attractiveness of average faces" *Psychological Science* **11** 285–289

Hills P J, Lewis M B, 2011 "The own-age face recognition bias in children and adults" *Quarterly Journal of Experimental Psychology* **64** 17–23

Jeon S T, Maurer D, Lewis T L, 2012 "Characterizing the mechanisms behind improvements in visual sensitivity during childhood" [Abstract] *Journal of Vision* in press

Johnson R W, Dannenbring G L, Anderson N R, Villa R E, 1983 "How different cultural and geographic groups perceive the attractiveness of active and inactive feminists" *Journal of Social Psychology* **119** 111–117

Kowner R, 1996 "Facial asymmetry and attractiveness judgment in developmental perspective" *Journal of Experimental Psychology: Human Perception and Performance* **22** 662–675

Langlois J H, Kalakanis L, Rubenstein A J, Larson A, Hallam M, Smoot M, 2000 "Maxims or myths of beauty? A meta-analytic and theoretical review" *Psychological Bulletin* **126** 390–423

Langlois J H, Roggman L A, Casey R J, Ritter J M, Rieser-Danner L A, Jenkins V Y, 1987 "Infant preferences for attractive faces: Rudiments of a stereotype?" *Developmental Psychology* **23** 363–369

Langlois J H, Roggman L A, Musselman L, 1994 "What is average and what is not average about attractive faces?" *Psychological Science* **5** 214–220

Langlois J H, Stephan C, 1977 "The effects of physical attractiveness and ethnicity on children's behavioral attributions and peer preferences" *Child Development* **48** 1694–1698

Lewis T, Ellemberg D, Maurer D, Dirks M, Wilkinson F, Wilson H, 2004 "A window on the normal development of sensitivity to global form in Glass patterns" *Perception* **33** 409–418

Little A C, Apicella C L, Marlowe F W, 2007 "Preferences for symmetry in human faces in two cultures: data from the UK and the Hadza, an isolated group of hunter-gatherers" *Proceedings of the Royal Society of London B* **274** 3113–3117

Little A C, Jones B C, 2006 "Attraction independent of detection suggests special mechanisms for symmetry preferences in human face perception" *Proceedings of the Royal Society B* **273** 3093–3099
Livshitz G, Kobylianski E, 1989 "Study of genetic variance in the fluctuating asymmetry of anthropometrical traits" *Annals of Human Biology* **16** 121–129
Low B, 2001 *Why Sex Matters: A Darwinian Look at Human Behavior* (Princeton, NJ: Princeton University Press)
Lu Z, Dosher B A, 1999 "Characterizing human perceptual inefficiencies with equivalent internal noise" *Journal of the Optical Society of America* **16** 764–778
Macchi Cassia V, 2011 "Age biases in face processing: The effects of experience across development" *British Journal of Psychology* **102** 816–829
Macchi Cassia V, Kuefner D, Picozzi M, Vescovo E, 2009 "Early experience predicts later plasticity for face processing" *Psychological Science* **20** 853–859
Manning J T, 1995 "Fluctuating asymmetry and body weight in men and women: implications for sexual selection" *Ethology & Sociobiology* **16** 145–163
Manning J T, Koukourakis K, Brodie D A, 1997 "Fluctuating asymmetry, metabolic rate and sexual selection in human males" *Evolution & Human Behavior* **18** 15–21
Mealey L, Bridgestock R, Townsend G C, 1999 "Symmetry and perceived facial attractiveness: A monozygotic co-twin comparison" *Journal of Personality and Social Psychology* **76** 151–158
Melnik A K, 1992 "A cephalometric study of mandibular asymmetry in a longitudinally followed sample of growing children" *American Journal of Orthodontics and Dentofacial Orthopedics* **101** 355–366
Møller A P, 1990 "Fluctuating asymmetry in male sexual ornaments may reliably reveal male quality" *Animal Behaviour* **40** 1185–1187
Møller A P, 1997 "Developmental stability and fitness: a review" *The American Naturalist* **149** 916–932
Møller A P, Pomiankowski A, 1993 "Fluctuating asymmetry and sexual selection" *Genetica* **89** 267–279
Møller A P, Swaddle J P, 1997 *Developmental Stability and Evolution* (Oxford: Oxford University Press)
Møller A P, Thornhill R, 1998 "Bilateral symmetry and sexual selection: A meta-analysis" *The American Naturalist* **151** 174–192
Mondloch C, Le Grand R, Maurer D, 2002 "Configural face processing develops more slowly than featural face processing" *Perception* **31** 553–566
Mondloch C J, Maurer D, Ahola S, 2006 "Becoming a face expert" *Psychological Science* **17** 930–934
Özener B, 2010 "Brief communication: Facial fluctuating asymmetry as a marker of sex differences of the response to phenotypic stresses" *American Journal of Physical Anthropology* **143** 321–324
Özener B, Fink B, 2010 "Facial symmetry in young girls and boys from a slum and a control area of Ankara, Turkey" *Evolution and Human Behavior* **31** 436–441
Penton-Voak I S, Jones B C, Little A C, Baker S, Tiddeman B, Burt D M, Perrett D I, 2001 "Symmetry, sexual dimorphism in facial proportions and male facial attractiveness" *Proceedings of the Royal Society of London B* **268** 1617–1623
Perrett D I, Burt M B, Penton-Voak I S, Lee K J, Rowland D A, Edwards R, 1999 "Symmetry and human facial attractiveness" *Evolution and Human Behavior* **20** 295–307
Perrett D I, May K A, Yoshikawa S, 1994 "Facial shape and judgments of female attractiveness" *Nature* **368** 239–242
Pomerantz J R, 1977 "Pattern goodness and speed of encoding" *Memory & Cognition* **5** 235–241
Ramsey J L, Langlois J H, Marti C N, 2005 "Infant categorization of faces: Ladies first" *Developmental Review* **25** 212–246
Ramsey-Rennels J L, Langlois J H, 2006 "Infants' differential processing of female and male faces" *Current Directions in Psychological Science* **15** 59–62
Reber R, Schwartz N, Winkielman P, 2004 "Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience?" *Personality and Social Psychology Review* **8** 364–382
Rennels J L, Simmons R E, 2008 "Facial experience during the first year" *Infant Behavior and Development* **31** 665–678

Rhodes G, 2006 "The evolutionary psychology of facial beauty" *Annual Review of Psychology* **57** 199–226
Rhodes G, Geddes K, Jeffery L, Dziurawiek S, Clark A, 2002 "Are average and symmetric faces attractive to infants? Discrimination and looking preferences" *Perception* **31** 315–321
Rhodes G, Leopold D A, 2011 "Adaptive norm-based coding of face identity", in *The Oxford Handbook of Face Perception* Eds A J Calder, G Rhodes, M H Johnson, J V Haxby (Oxford: Oxford University Press) pp 263–286
Rhodes G, Louw K, Evangelista E, 2009 "Perceptual adaptation to facial asymmetries" *Psychonomic Bulletin & Review* **16** 503–508
Rhodes G, Peters M, Lee K, Concetta Morrone M, Burr D, 2005 "Higher-level mechanisms detect facial symmetry" *Proceedings of the Royal Society of London B* **272** 1379–1384
Rhodes G, Proffitt F, Grady J M, Sumich A, 1998 "Facial symmetry and the perception of beauty" *Psychonomic Bulletin & Review* **5** 659–669
Rhodes G, Yoshikawa S, Clark A, Lee K, McKay R, Akamatsu S, 2001 "Attractiveness of facial averageness and symmetry in non-Western cultures: in search of biologically based standards of beauty" *Perception* **30** 611–625
Samuels C A, Butterworth G, Roberts T, Graupner L, Hole G, 1994 "Facial aesthetics: babies prefer attractiveness to symmetry" *Perception* **23** 823–831
Saxton T K, Debruine L M, Jones B C, Little A C, Roberts S C, 2009 "Face and voice attractiveness judgments change during adolescence" *Evolution and Human Behavior* **30** 398–408
Saxton T K, Debruine L M, Jones B C, Little A C, Roberts S C, 2011 "A longitudinal study of adolescents' judgments of the attractiveness of facial symmetry, averageness and sexual dimorphism" *Journal of Evolutionary Psychology* **9** 43–55
Saxton T K, Kohoutova D, Roberts S C, Jones B C, DeBruine L M, Havlicek J, 2010 "Age, puberty and attractiveness judgments in adolescents" *Personality and Individual Differences* **49** 857–862
Scheib J E, Gangestad S W, Thornhill R, 1999 "Facial attractiveness, symmetry and cues of good genes" *Proceedings of the Royal Society of London A* **66** 1913–1917
Simmons L W, Rhodes G, Peters M, Koehler N, 2004 "Are human preferences for facial symmetry focused on signals of developmental instability?" *Behavioral Ecology* **15** 864–871
Slater A, Quinn P C, Hayes R, Brown E, 2000 "The role of facial orientation in newborn infants' preference for attractive faces" *Developmental Science* **3** 181–185
Slater A, Von der Schulenburg C, Brown E, Badenoch M, Butterworth G, Parsons S, Samuels C, 1998 "Newborn infants prefer attractive faces" *Infant Behavior and Development* **21** 345–354
Thornhill R, Gangestad S W, 1994 "Human fluctuating asymmetry and sexual behavior" *Psychological Science* **5** 297–302
Thornhill R, Møller A P, 1997 "Developmental stability, disease and medicine" *Biological Reviews* **72** 497–548
Thornhill R, Sauer P, 1992 "Genetic sire effects on the fighting ability of sons and daughters and mating success of sons in a scorpionfly" *Animal Behaviour* **43** 255–264
Tiddeman B, Burt D M, Perrett D, 2001 "Computer graphics in facial perception research" *IEEE Computer Graphics and Applications* **21** 42–50
Trivers, R L, 1972 "Parental investment and sexual selection", in *Sexual Selection and the Descent of Man, 1871–1971* Ed. B Campbell (Chicago, IL: Aldine-Atherton) pp 136–179
Trivers R L, Manning J T, Thornhill R, Singh D, McGuire M, 1999 "Jamaican Symmetry Project: Long-term study of fluctuating asymmetry in rural Jamaican children" *Human Biology* **71** 417–430
Vingilis-Jaremko L, Maurer D, in press, "The influence of averageness on children's judgments of facial attractiveness" *Journal of Experimental Child Psychology*
Wade 2010 "The relationships between symmetry and attractiveness and mating relevant decisions and behavior: A review" *Symmetry* **2** 1081–1098
Wagemans J, 1995 "Detection of visual symmetries" *Spatial Vision* **9** 9–32
Watkins C D, Jones B C, Little A C, DeBruine L M, Feinberg D R, 2012 "Cues to the sex ratio of the local population influence women's preferences for facial symmetry" *Animal Behaviour* **83** 545–553

Waynforth D, 1998 "Fluctuating asymmetry and human male life-history traits in rural Belize" *Proceedings of the Royal Society of London B* **265** 1497–1501
Wenderoth P, 1994 "The salience of vertical symmetry" *Perception* **23** 221–236
Wilson J M, Manning J T, 1996 "Fluctuating asymmetry and age in children: evolutionary implications for the control of developmental stability" *Journal of Human Evolution* **30** 529–537
Winkielman P, Halberstadt J, Fazendeiro T, Catty S, 2006 "Prototypes are attractive because they are easy on the mind" *Psychological Science* **17** 799–806